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STREETWALL AND PLOT PATTERN: CASE STUDIES IN NANJING, CHINA

Abstract: *Streetwall is composed of street buildings, which form is the result of three aspects such as city regulations, land use indicators and plot pattern (Talen, 2012). As plot is the basic unit that city regulation and land use play their roles, it is proved that plots with its size, shape and quantity do affect the shape of the streetwall (Tang, 2017). But specific to the detailed mathematic relationships between plot pattern and the streetwall continuity index such as interface density, the study needs to be continued to ensure that the results can be used to control the streetwall in urban design process, especially in modern cities. Therefore, based on certain settings of city regulations and land use indicators, the paper tries to find the mathematical relations between plot size, quantity and indicators and the streetwall continuity. Firstly, several street samples are built based on the statistics of block size, plot size, plot quantities, plot orientation and land use indicators in Nanjing City, China. The samples correspond to several types of size combination, types of land-use combination, and types of land use indicators. Secondly, based on the existing urban regulations since 2007, numerous designs on the plots of different type are experimented; the intervals of the length and the distance between buildings are calculated. Finally, interface density of the streetwall samples is calculated and the mathematics relationships between them and sub-road and plot size, quantity are established. The paper concludes in several mathematical formulas considering different types of street, and concludes the minimum and maximum of the plot size and quantity, which correspond to the most discontinuous and most continuous streetwalls.*

Keywords: *streetwall, streetwall continuity, plot pattern, street buildings.*

Introduction

Urban design plays an important role in controlling the physical form of urban space, in the process of urban regeneration and urban space optimization in Chinese cities. By controlling the buildings' forms along the street, urban design reshapes the street space, optimizes the quality of space, which is related to the streetscape, comfortability and activity that people experience in the city. In the control method, urban design guidelines carry out quantitative indicators such as build-to-line ratio, interface density to control the buildings' form. However, because of the complexity of the plots in the city center, the indistinct between the effects of existing city rules, and the multiple standard of space quality, the indicators are difficult to implement in many actual situations. Therefore, in order to control the urban form more effectively in the urban design, the corresponding basic researches need to be carried out based on the basic theory of urban morphology (Ding, 2013). The study on the influence of the plots pattern combined with the construction regulations on the streetwall is one of the important ones.

Streetwall is composed of street buildings, which form is the result of three aspects such as city regulations (Talen, 2012; Marshall, 2011), land use indicators and plot pattern. Different from the city rules of cities in Europe and the United States, which are made considering safety, health, economy as well as beauty and people's perception (Barnett, 2011; Green, 2011; Kropf, 2011; Talen, 2012), the city rules in China are mainly based on the requirement of security and health. As a result of the high construction speed, the regulations were updated also very fast, in Nanjing, for example, from 1995 to 2007, the setting back rules were updated in four times. Meanwhile, as plot is the basic unit that city regulation and land use play their roles, it is proved

that plots with its size, shape and quantity do affect the shape of the streetwall (Tang, 2017). The plot pattern in Chinese cities is the result of historical and cultural development (Zhang, 2018). Due to historical factors, the shape of the plots is irregular, the size is varied, and the density of plots along one street is dense or loose. Under the influence of the changing urban construction regulations, the complex features of the plots make the streetwall more disordered in the process of urban regenerations.

Therefore, based on the newest city regulations, the paper tries to find the mathematical relations between plot size, quantity and the streetwall continuity, by casing Nanjing city, China. Firstly, based on the physical features of streets in Nanjing City, the paper constructs an ideal model of streetwall and sets series of parameters to express various sizes and relations. The thresholds of these parameters are set based on the present urban morphological features, and the mathematical relationship between the parameters and evaluation index of streetwall is established. Secondly, according to the interval of threshold value, the paper studies the mathematics relationships between the quantity of branches and the plots along the street and interface density value, under the precondition of different street widths and building heights.

Methodology

1. Parameter Setting

The construction of the ideal model needs to conform to the characteristics of Chinese urban form. It has been shown that compared with European cities, the scale of Chinese urban blocks varies greatly, and it is more suitable to be expressed in two levels. Lin (2015) proposed that it is necessary to define block and sub-block to distinguish the blocks enclosed by freeway, main road and secondary road, with the blocks enclosed by branch road and others. It means that block may include several sub-blocks. Therefore, the length of the streetwall model is set to the one-sided length of a block. In this section of the street, the quantity of branch roads determines the one of the sub-blocks, in which the quantity, size, and land use of the plot all determine the form of the streetwall.

Thus, many related parameters need to be set and describe its exact meaning (Fig. 1). These parameters include several layers: the parameters that describe the feature of a block – length of block, branch road quantity, plots quantity and so on; the parameters that describe the characteristics and capacity of the plots – length of plot, land use, FAR and so on; and the parameters that describe the features of the buildings – building quantity, length of buildings along the street, distance between the buildings. In addition, there are some parameters to express the setback of the buildings.

2. Measurement settlement

2.1. Urban rules affecting the form of streetwall

Streetwall was not built in a day. The street buildings were built in different periods, and the form was influenced by the construction regulations at the time, the planning index and the plot form. The study of historical urban rules on streetwall helps us understand the emergence of urban forms, but future urban construction is based on current and future rules. Therefore, the study is based on the current rules that affect the form of streetwalls directly or indirectly (Fig.2).

Regulations with direct influences on forms of buildings along streets include a minimum setback line, minimum building setback boundary, minimum building spacing, height control in planned indices, etc. In accordance to the existing Implementing Rules for Urban Planning of Nanjing (2007), different setbacks are specified for buildings with a height of less than 24m, buildings within a height range of 24-100m and buildings with a height of over 100m on two sides of roads which are over 30m and less than 30m wide; aiming at residential buildings with a height of 24m, buildings within a height range of 24-35m, and buildings with a height of over 24m, different setbacks to boundaries are specified according to the face widths of the buildings (Fig.3).

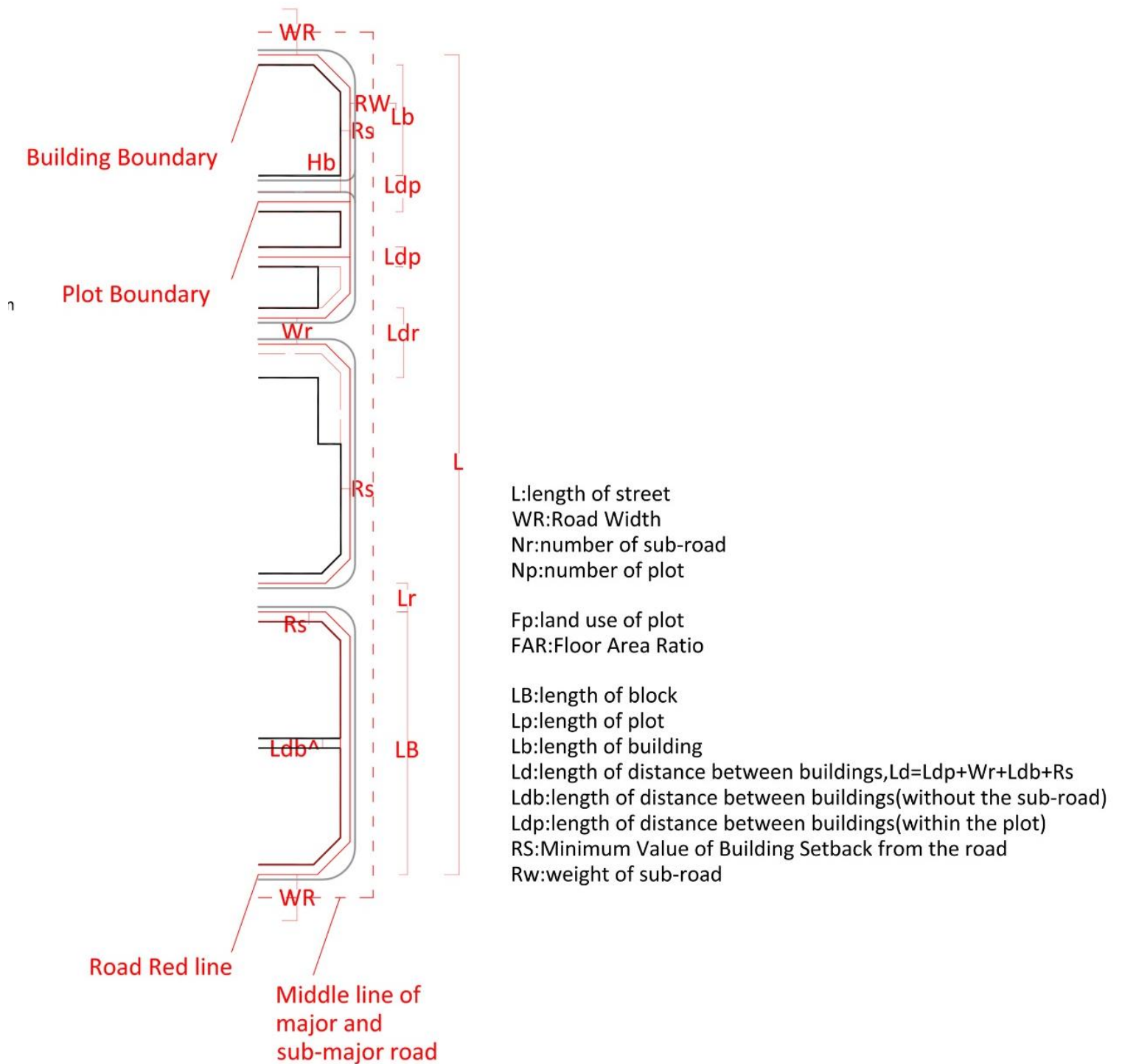


Figure 1. Parameter setting

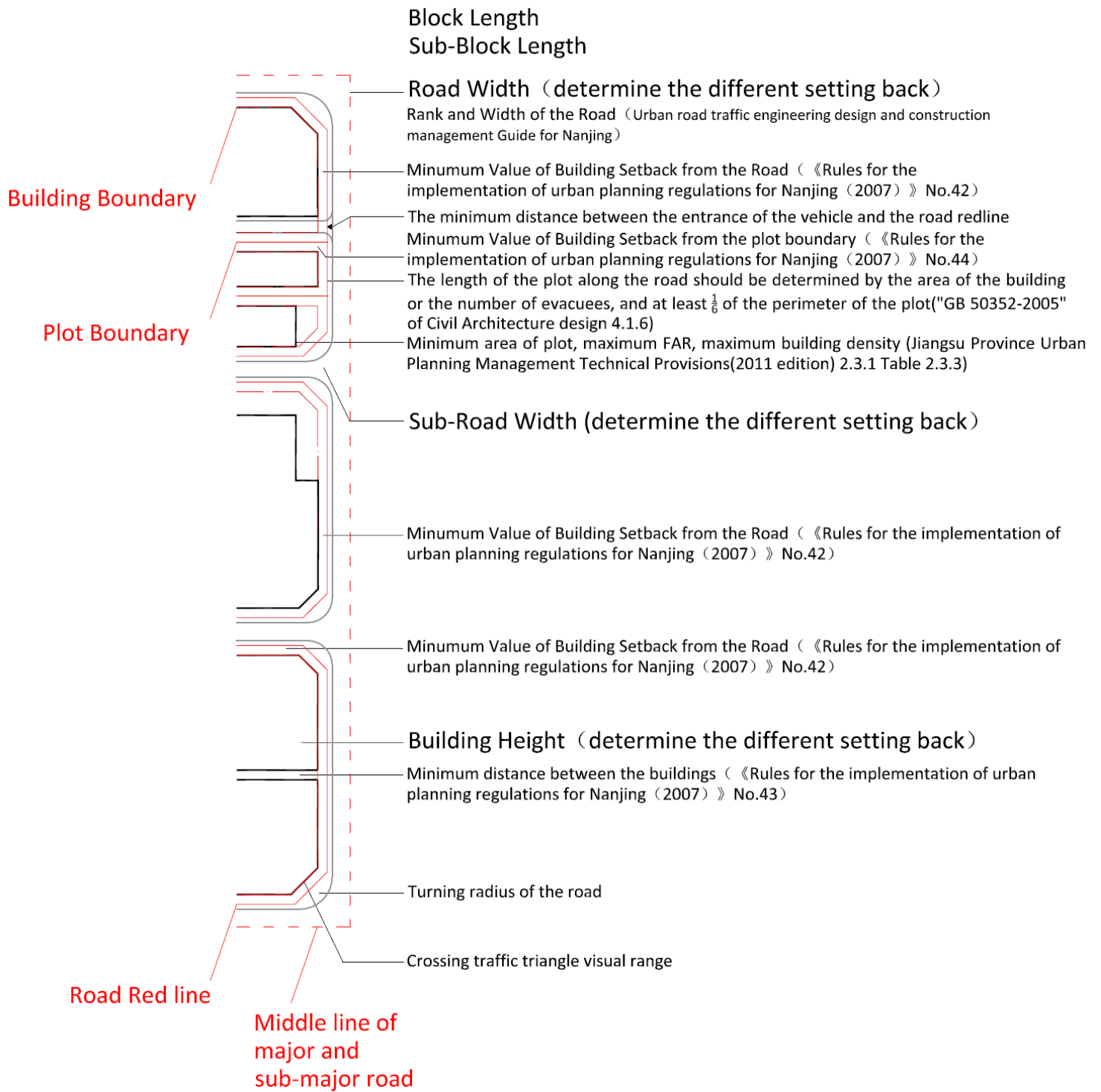


Figure 2. Urban rules affecting the form of streetwall

Building Height	Minimum Setback from the road which width over 30m	Minimum Setback from the road which width below 30m
Below 24m	6m	4m
Between 24m and 100m	15m	12m
Over 100m	25m	18m

Function	Building Height	Building Width	Minimum setback from the plot boundary
All	Below 24m	below 15m	4m
All	Below 24m	Over 15m	6m
Residential	24-35m	Below 20m	8m
Residential	24-35m	Over 20m	10m
All	Over 24m	Below 25m	10m
All	Over 24m	Over 25m	15m

Figure 3. Current setback regulations of Nanjing City (2007)

Regulations with indirect influences on the forms of buildings along streets include regulations for the minimum area/maximum plot ratio/maximum building density of lands, minimum distances from lands to urban roads, minimum distances from automobile exits in blocks to road boundaries, minimum plot ratio/road width/spacing between entrance and exit/minimum building setback line, radius of road turns/triangular stadia for driving at road crossings. Technical Regulation on Urban Planning Management in Jiangsu Province specifies the building base control index, besides regulating the minimum area of building base of residential building and non-residential building of different heights; it also regulates the maximum value of building density and plot ratio. To the building of some type, the plot ratio and building density are restricted. For example, the maximum value of base area of multi-storey residence is 1000m², the building density cannot be more than 28% in new area, cannot be more than 30% in the old area, the plot ratio in new area cannot be 1.7, and cannot be more than 1.8 in the old area.

Other factors include the widths of adjacent roads (determining different setbacks), the width of sub-roads (determining different setbacks), building design codes, etc. Besides the regulation on building setback, capacity control, etc., fire protection, daylighting spacing, etc also regulate the position of frontage building. For example, according to the regulation of firefighting law, “when the length of frontage building is more than 160m, no less than 4m*4m fire lane shall be set. The pedestrian exit spacing should not be more than 80m, when the building length is more than 80m, pedestrian passage shall be added on the base floor;” the building length is restricted by this regulation. For another example, to residential building, daylighting spacing is especially strict, when the frontage building is residential building, the position setting shall also consider the shielding from the existing building in the south.

2.2. Values interval of blocks, branch roads, and plots

Block and sub-block length : The model is established on the basis of the urban form of Nanjing. Set parameter thresholds should meet the characteristics of the urban form of Nanjing, specifically including the length of streets, the quantity of sub-roads in a street block, the quantity of lands along a street, land widths, etc. For this purpose, this research statistically studied the values of those parameters in the old urban area and new urban area of Nanjing, and their maximum values, minimum values, average values, statistical quantities and average variances of those parameters on each of the two sides of each one of the roads such as east-west and south-north main roads and secondary roads, and finally obtained the value intervals according to the distribution intervals of those values (Fig. 4). For example, for the south-north main roads, the road width is usually 80m, the street block width is usually 200-700m, and the

width of secondary street blocks is usually within a range of 100-400m. In the old urban area, the road width of the east-west secondary roads is usually within a range of 28-33m; the street block width is usually within the range of 55 -700m; and the width of secondary street blocks is usually within the range of 31-400m.

Road type	New city			Old city		
	Road width	Block width	Sub-block width	Road width	Block width	Sub-block width
Freeway S-N	50-60m	500-1000	200-500	40-52m	100-1400	100-500
Freeway E-W	60m	100-1200	200-500	40-52m	100-1200	100-200
Main road S-N	80m	200-700	100-400	40-52m	100-900	35-400
Main road E-W	40m	200-600	100-400	40m	100-700	49-400
Secondary road S-N	28-40m	200-800	100-400	28-36m	100-700	25-500
Secondary road E-W	35-40m	200-600	100-400	28-33m	55-700	31-400
Branch road S-N	16,24,28,33m	-	-	12,16,20,24m	-	-
Branch road E-W	16-28m	-	-	16,24m	-	-
River	-			-		

Figure 4. Values Interval of blocks, branch roads, and plots

In addition, this research also statistically calculated the quantity of sub-roads in each street block. There are fewer sub-roads in the new urban area, usually in a number of 0-4. There are more sub-roads in the old urban area, usually in a number of 0-9. For the quantity of lands in each segment of secondary street blocks, usually 1-4, 5 and 7 pieces of lands are distributed along a street in the new urban area and 1-10 pieces of lands along a street in the old urban area.

According to statistics, the number of branches in the urban district takes 0-4, and the old Town is 0-9. The number of plots in each sub block is 1-4, 5, 7; the old Town takes 1-10.

3. Establish a relationship between parameters and evaluation indices

3.1. Quantitative indices

In order to ensure visual "continuity and orderliness" and in order to ensure continuity of activities along a street, a series of evaluation indices for describing and controlling street wall forms are put forward, not only in the research but also in practice. Those evaluation indices include interface density, build-to-line ratio, rate of convergence, average rate, etc (Zhou, 2012). Among those indices, the most frequently used index is the build-to-line ratio which can be obtained by different methods.

For this research, a common easy calculation method is selected to describe the relationship between streetwalls and roads, which is similar to the interface density calculation method. Such calculation method mainly describes the ratio of the total projection length of a building to the total length of a street where the building is located, and a main factor affecting the value is the spacing between buildings along the street. The unevenness of the building interfaces caused by different setbacks is not described at present. This is because the subject of this research is to describe the influences of sub-road quantity and land division on the street wall form. The influences of those two factors are mainly reflected on the spacing between buildings.

3.2. Indexes and calculation methods used in this paper

For this reason, the calculation method adopted in this text employs the above mentioned parameters (Fig.5). The following formula can be used to express the relationship. The denominator in the formula is uniformly the total length of a single side of a primary street block. The spacing between buildings varies with the following situations: total building setbacks from main and secondary roads; if there are sub-roads, the spacing is equal to the sum of the widths of the sub-roads and the building setbacks from the corresponding sub-roads; due to the

boundaries among lands, the spacing is equal to the sum of the setbacks of the buildings in each land from the corresponding boundaries; the total spacing between buildings generated by firefighting, design, etc. Finally, the total length of the building projection is divided by the total length of a single side of a street block to obtain the value of the interface density required in this text.

$$\begin{aligned}
 L_d &= L_{dp} + W_r + L_{db} + R_s \\
 L &= (L_{b1} + L_{b2} + \dots + L_{bi}) + (W_{r1} + W_{r2} + \dots + W_{rm}) + \\
 &\quad (R_{s1} + R_{s2} + \dots + R_{sn}) + (L_{db1} + L_{db2} + \dots + L_{dbj}) \\
 &= \sum L_b + \sum L_{dp} + \sum W_r + \sum L_{db} + \sum R_s \\
 \sum L_b &= L - (\sum L_{dp} + \sum W_r + \sum L_{db} + \sum R_s)
 \end{aligned}$$

\downarrow
 N_p
 H_b
 L_b

\downarrow
 N_r
 W_r

\downarrow
 F_p
 H_b
 L_b

\downarrow
 H_b
 L_b

$$\text{Interface Density } D_i = \sum L_b / L$$

Figure 5. Calculation methods used in the paper

Statistics and analysis

Then, the sub-road quantity and plot quantity, etc. are used as variables in this research to specifically analyze changes in the interface density along with the changes in those variables.

1. Sub-road quantity and interface density

Obviously, more sub-roads lead to smaller interface density values in the street block. Specifically, the average street block length is set at 400m, and the sub-road width is set at 16m in the new urban area. When the sub-road quantity increases from 0 to 4, the interface density decreases progressively from 0.97 to 0.73; when the sub-road width is 33m, the interface density is progressively decreased to 0.52. This is to say that when a street block with a length of 400m has four 33m long sub-roads, the ratio of the projection length of the building elevation to the total length of the street is at most approximately 0.5. Channels and plazas reserved according to the building design are not included. In the new urban area, the shortest length of a street is less than 100m. When there are three 16m long sub-roads within the 100m range, the maximum building interface density is 0.16. This means that for shorter street blocks, the building interface density within the street block can be greatly affected each time a sub-road is added.

For the old urban area, statistically, at most nine sub-roads are distributed within the range of a street block. For street blocks with an average length of 500m, the interface density can only reach 0.4 when there are nine sub-roads. The shortest street block in the old urban area is only 55m long. When there are two sub-roads in the street block and the road width is 12m, the calculated value of the interface density is only 0.05. Compared with the new urban area, the sub-road in the old urban area is relatively shorter, but more sub-roads are distributed on a single side of a street block. If setbacks are set according to the existing regulations, it is impossible to construct some buildings or the face widths of buildings may be very small. For example, when a street is 200m long and there are six 24m long sub-roads, the calculated value of the interface density is -0.02, so construction is impossible. (Fig. 6).

2. Plot quantity and interface density

An increase in plot quantity forces buildings to be set back from more land boundaries. As the plot quantity increases, the interface density correspondingly decreases. The side length of a

street block, the widths of adjacent roads, the building sizes, and building heights may all influence the interface density. Under the same conditions, the setback is minimum and the interface density is relatively large if the building height is less than 24m. For common secondary street blocks with a length of 200m, the interface density value is only 0.4 when the plot quantity is 10; for secondary street blocks with a length of 400m, the interface density decreases from 0.97 to 0.7 as the plot quantity changes from 1 to 10.

For primary street blocks, in conjunction with the influences of the sub-road quantity, the interface density within the length range of a primary street block also progressively decreases as the plot quantity increases. For example, when the sub-road quantity is 1, the interface density of a 400m long primary street progressively decreases from 0.905 to 0.665 as the plot quantity increases from 2 to 10. (Fig. 7 left)

3. Street block length/building height and interface density

In addition, when other conditions are unchanged, the progressive decrease amplitude of the interface density gradually becomes smaller as the calculating denominator value of a primary street becomes larger. For example, when the length of a primary street is 100m, the plot quantity has a larger influence than that in the case when the street length is 500m.

Building height influences in a way that a higher building leads to a larger setback from a road or a land boundary within a certain range. For example, when a building has a height of less than 24m, the setback from a sub-road with a length of less than 30m is 4m, and the setback from a land boundary is 4m or 6m upon the face width of the building; when a building has a height within a range of 24-100m, the setback from a sub-road is 12m; when a building is with a height of over 100m, the setback from a sub-road is 18m, and the setback from a land boundary is 8m, 10m or 15m upon the function type and face width of the building. This influences the calculated value of the building density greatly. For example, under the conditions of a 500m long primary street, 3 sub-roads, 6 pieces of lands, and over 25m building face width, the interface density value is, respectively, 0.772, 0.604, 0.532 when the building height is, respectively, 24m, within the range of 24-100, and over 100m (Fig. 7 Right). The interface continuity of the street is greatly influenced. For this reason, multi-story or high-rise buildings are usually configured with podium buildings in real.

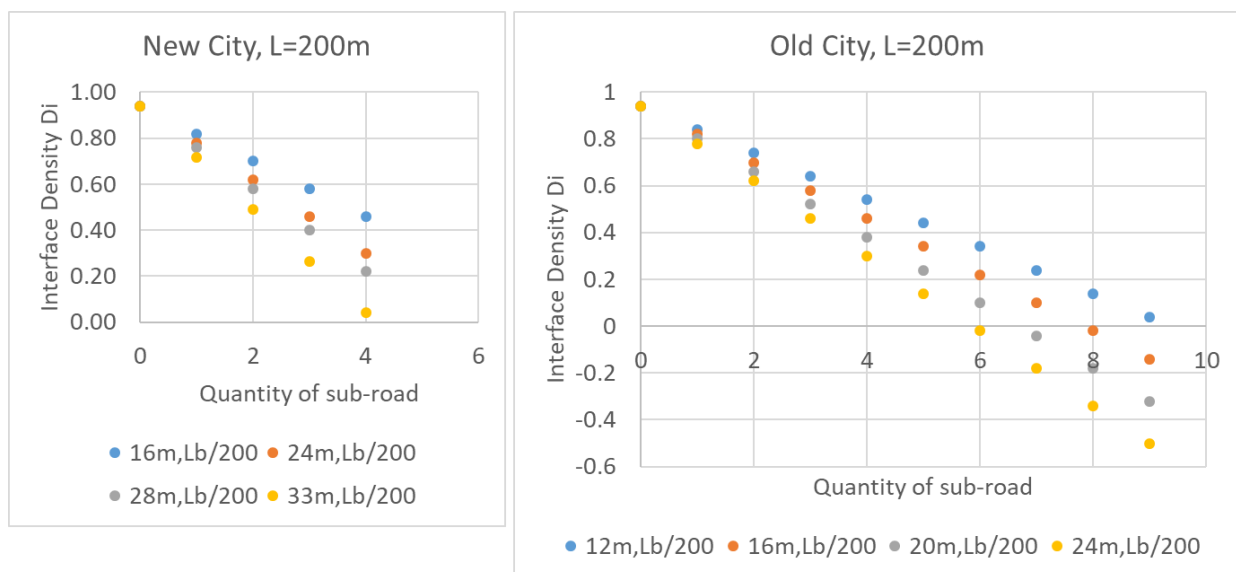
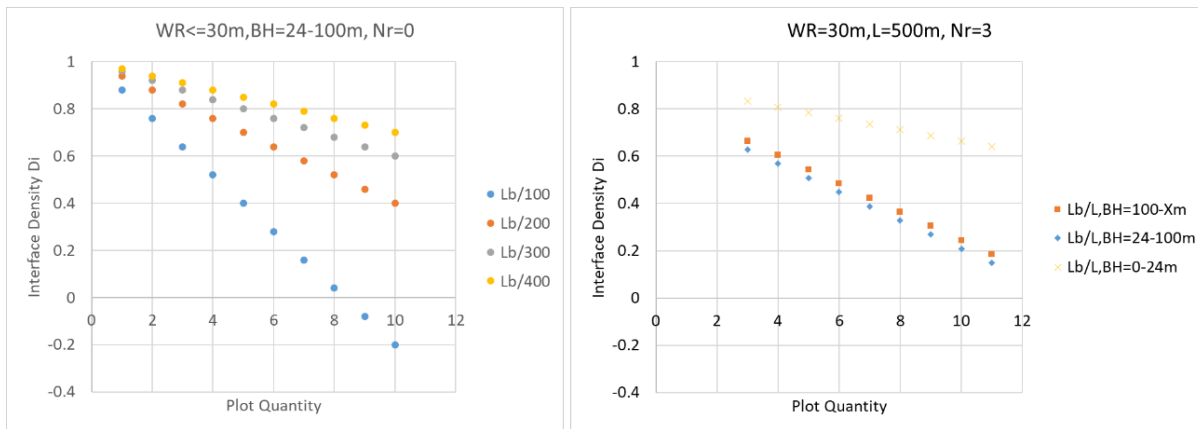


Figure 6. Interface density (D_i) and sub-road quantity

Figure 7. Interface density (D_i) and plot quantity

Conclusion and discussion

Based on the analysis of the existing planning regulations which has influence on the form of the streetwall and on the statistics of the features of street/block/plot of Nanjing City, the Numerical characteristics of plot pattern in Nanjing old city and new city has been calculated and analyzed. Based on the statistics of the plot pattern along streets, the ideal model is made and the formulas of interface density are built. The accurate mathematics relationship between the quantity of sub-roads, plots, building height, etc. and D_i are tabled, which will support the further urban design. The goal of changing the form of the streetwall is possible to be achieved only by changing the setback regulations according to the quantity of branches and plots.

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